LBNL ELECTRICAL EQUIPMENT ACCEPTANCE PROGRAM

1 Introduction

The Occupational Safety and Health Administration (OSHA) and the National Electrical Code (NEC) specify that electrical equipment is allowable for use in the workplace only if it has been accepted by the Authority Having Jurisdiction (AHJ). Equipment that has been Listed or Accepted by a Nationally Recognized Testing Laboratory (NRTL) is considered to be acceptable to the Authority Having Jurisdiction. Equipment that has NOT been Listed or Accepted by a Nationally Recognized Testing Laboratory (NRTL) is not acceptable to the Authority Having Jurisdiction unless it has satisfactorily passed a documented safety analysis. In order to meet this requirement LBNL has established the Electrical Equipment Inspection Program (EEIP).

2. Equipment Requirements

1. This program applies to all electrical equipment that has a potential of 50 Volts or greater anywhere in the equipment. This includes any equipment that uses or connects to utility voltage (120-volts or greater), even if the voltage is reduced to less than 50 volts for utilization.
    a. Exceptions:
        i. Equipment that does not connect to a source of utility power, e.g., battery powered, and is current-limited to .005 Amps does not require further evaluation.

2. Electrical equipment that has been Listed or Accepted by a NRTL, is being used in accordance with its manufacturing and Listing intent, is undamaged, and unmodified, may be used without any further approval process. This equipment is not required to be labeled or documented.

3. All newly purchased electrical equipment shall be NRTL-Listed or Accepted. If there is a choice between purchasing an NRTL- Listed or Accepted product and one that is not Listed or Accepted, the Listed or Accepted product shall be purchased. If the desired product type cannot be purchased as a Listed or Accepted product, the product shall be required to be inspected and accepted by the EEIP before being used. Individual electrical components (e.g., resistors, relays, etc) that are purchased to be used in finished assemblies are not required to be individually NRTL- Listed or Accepted, although this is desirable.

4. Newly purchased equipment with a purchase price of $50,000 or greater shall be NRTL-Listed or Accepted. If the manufacturer does not provide an NRTL-Listing, the equipment shall undergo an NRTL Field Evaluation and be found to be acceptable before being used (See 6.4). The Field Evaluation shall be at the expense of the equipment requestor's organization. The estimated cost of a NRTL Field Evaluation is between $2000 - $5000 for most equipment.

5. Electrical equipment that is labeled as a Recognized Component (rather than a Listed or Accepted field-installable product) shall be inspected by the EEIP and found to be

acceptable, before being used. An assembly of components shall be evaluated as a single construction.

6. **EQUIPMENT SURVEY:** All Divisions are responsible for surveying their own equipment and documenting existing non-NRTL programmatic equipment that will require examination. NRTL- Listed or Accepted equipment is not required to be surveyed and documented. Survey training, assistance, and database services will be provided by the EEIP. Divisions shall enter the equipment data into the inspection database. The equipment survey shall be completed by 10-1-09.

7. **EXISTING (LEGACY) EQUIPMENT:** All electrical equipment present at LBNL before February 1, 2009, is required to be inspected and found Acceptable by Sept. 30, 2012. Any equipment not Accepted by this time shall be removed from service. The AHJ conditionally accepts this equipment, and allows it to be used pending inspection, but no later than Sept. 30, 2012.

8. **LAB-MADE EQUIPMENT:** The protocols for Lab-made equipment shall be the same as for purchased equipment. All Legacy equipment shall be surveyed and documented in the EEIP database by Sept. 30, 2009. This equipment is conditionally accepted for use pending inspection, but no later than Sept 30, 2012. All newly constructed equipment shall be required to be found acceptable to the EEIP before being placed into use.

9. **REPAIRS:** Equipment that has been previously found to be Acceptable does not require re-inspection when repaired by qualified individuals using like-for-like repair parts. Equipment that is being modified from its original design shall be re-evaluated and found Acceptable to the AHJ before being used.

3. Responsibilities

3.1 Authority Having Jurisdiction (AHJ) See Pub 3000 Ch 8

At LBNL, the Authority Having Jurisdiction is divided along three lines. The EH&S Electrical Safety Engineer is the AHJ for Electrical Safety, delegated by the Director of EH&S. The Facilities Division Director is the AHJ for infrastructure electrical equipment and the installation of power distribution and premises wiring. The Facilities Director may delegate this authority to an appropriately qualified electrical engineer. The Engineering Division Director is the AHJ for the design, installation, maintenance, and repair of research and development (R&D) and experimental equipment. All three of these AHJ designations have some responsibility for electrical equipment. Because the acceptance of electrical equipment is an Electrical Safety issue, the EH&S Electrical Safety Engineer will coordinate and administer this process.

3.2 EEIP Manager (Electrical Safety AHJ) Responsibilities

The EEIP Manager is the LBNL EH&S Electrical Safety Engineer or his appointed

representative. The EEIP manger is responsible for coordinating and administering the program, with the assistance of EEIP Field Representatives and the Electrical Safety Committee (ESC). This office has authority to accept for use, with respect to electrical safety, programmatic electrical equipment and installations.

Responsibilities include:

1. Collaborate with all LBNL Electrical AHJs on the establishment and standardization of this program.
2. Establish inspection criteria in accordance with appropriate electrical safety Standards.
3. Establish training and qualification program for EEIP Field Representatives
4. Maintain a staff of trained EEIP Field Representatives.
5. Use the EEIP database to track equipment surveys and arrange inspections accordingly.
6. Inspect newly purchased equipment in a timely manner.
7. Inspect Legacy equipment by Sept.30, 2012.
8. Oversee EEIP inspection process and provide quality assurance.
9. Establish training for Divisions as necessary for equipment surveys and other compliance issues.
10. Maintain equipment inspection database
11. Promote the program throughout the Laboratory.
12. Perform technical assurance reviews as necessary

3.3 Engineering Division / AHJ Responsibilities

Responsibilities include:

1. Collaborate on standardizing acceptance criteria for equipment
2. Ensure that R&D equipment fabricated and repaired by Engineering meets all relevant standards.
3. Ensure that engineering designs incorporate all required safety features.

3.4 Facilities Division / AHJ Responsibilities

Responsibilities include:

1. Ensure that all installed electrical equipment that is associated with premises wiring or infrastructure is Acceptable.
2. Ensure that all premises wiring and infrastructure electrical installations comply with the NEC .
3. Collaborate on standardizing acceptance criteria for equipment.
4. Ensure that all Facilities-owned non-NRTL equipment is appropriately labeled and entered into the database.
5. Designate a sufficient number of employees to be trained as Field Representatives.
6. Inspect all Facilities-owned non-NRTL equipment and enter results into the database.

3.5 LBNL Electrical Safety Committee

The Electrical Safety Committee (ESC) advises on electrical safety matters and promotes electrical safety at LBNL. The ESC will be a resource to aid in the development of inspection criteria, training, and program administration. If there is a disagreement that cannot be resolved by the EEIP Manager, this group will hold a hearing to facilitate resolution.

3.6 Division / Program Responsibilities

All Divisions are responsible for:

1. Conducting surveys to identify and document non-NRTL equipment within their organization.
2. Applying AHJ Barcode labels to the non-NRTL equipment and entering the identification into the database before Sept. 30, 2009.
3. Notifying the EEIP of any new non-NRTL equipment being purchased.
4. Arranging for inspections.
5. Making corrections to equipment in accordance with the inspection findings
6. Removing equipment from service that has been labeled “failed”.
7. Obtaining NRTL-Field Evaluations for procured equipment that exceeds $50,000 value.

3.7 Equipment Supervisor Responsibilities

All Equipment Supervisors are responsible for:

1. Cooperating with the EEIP throughout the survey and inspection process.
2. Ensuring that all of their Legacy electrical equipment has been identified before Sept. 30, 2009.
3. Specifying for purchase only NRTL equipment, if possible.
4. Promptly notifying the EEIP of any non-NRTL equipment that has been ordered.
5. Arranging inspection of procured non-NRTL equipment before placing into service. (See 2.7 for Legacy Equipment)
6. Ensuring that equipment is corrected and reinspected as necessary.
7. Complying with any conditions placed on equipment by an inspector.
8. Arranging inspection of new Lab-built apparatus before placing into service. (See 2.7 for Legacy Equipment)
9. Not using non-NRTL new equipment until it has been inspected and approved by an AHJ Field Representative.
10. Not using non-NRTL Legacy equipment after Sept.30, 2012, unless it has been inspected and approved by an AHJ Field Representative.
11. Removing from service any equipment found to be unsafe for use by an EEIP Field Inspector.

3.8 Procurement

1. All subcontracts and purchase orders that involve the delivery of any electrical products shall contain language such as the following:

   "Electrical Device Certification
   All delivered electrical equipment, components and conductors and other items of the type requiring testing by a Nationally Recognized Testing Laboratory (NRTL) recognized by the Occupational Safety and Health Administration (OSHA), shall be NRTL listed, labeled, or certified in accordance with Part 1910, /General Industry Standards/, of Title 29 of the Code of Federal Regulations (29 CFR 1910). The Subcontractor shall notify the University Procurement Representative or the University Technical Representative, if designated, in writing of any delivered Items that do not meet these requirements. If the Subcontractor does not provide this notification, the University reserves the right to refuse delivery or return the item."

2. If a subcontractor or vendor notifies the buyer that the desired product is not NRTL Listed or Accepted, the buyer shall notify the requestor.
3. The requestor shall specify an alternate product that is NRTL Listed or Accepted, if possible.
4. If no NRTL substitute is available, the buyer shall notify the EEIP program manager.
5. A Field Representative will be assigned to inspect the equipment before it is placed into service. Depending on the equipment, this inspection may require opening covers and access panels. The requestor is responsible for determining any impact this may have on warranties or returnability.
6. Newly purchased equipment with a purchase price of $50,000 or greater shall be NRTL-Listed or Accepted. If the manufacturer does not provide an NRTL-Listing, the equipment shall undergo an NRTL Field Evaluation and be found to be acceptable before being used (See 6.4). The Field Evaluation shall be at the expense of the equipment requestor's organization. The estimated cost of a NRTL Field Evaluation is between $2000 - $5000 for most equipment.

4 Equipment Surveys

1. All Divisions are responsible for surveying all of their own equipment before Sept. 30, 2009. The Division may designate as many equipment surveyors as is necessary. All designated surveyors are required to take a short self-study course (EHS 381) that may be downloaded at www.lbl.gov/ehs/training/. Upon completing the course, the surveyors will be issued a set of survey labels, and will be provided with password access to the EEIP database. Divisions that have a large amount of affected equipment are strongly encouraged to designate many surveyors in order to lessen the overall effort and ensure the surveys are completed in a timely manner. It is acceptable to designate one or more surveyors for each project in the Division.
2. Survey Criteria. All scientific / research equipment within the electrical requirements specified in 2.1, whether custom-built or commercially made, shall be surveyed to determine if it is NRTL –Listed or Accepted. Non-NRTL equipment shall be entered into the database. NRTL equipment shall not be entered into the database unless it has been modified or is being used for some purpose outside of the original design intent.

a. **Required** survey labeling: All equipment that is not NRTL-Listed or Accepted shall be labeled with an AHJ barcode, and the identifying information shall be entered into the database.
    i. If the equipment is in storage and not expected to be used, it shall be prominently labeled “AHJ Inspection Needed Before Using”. This equipment is not required to be bar-coded or recorded in the database.
b. **Optional** survey labeling: NRTL Listed or Accepted equipment may be optionally labeled with a green “NRTL Approved” sticker. The purpose of this label is to indicate that the surveyor found an NRTL mark somewhere on the equipment and no further action is required. Since the manufacturer’s NRTL mark is often on a less visible part of the equipment, using this sticker will prevent redundant observations, making the surveying process more efficient. This label is not mandatory, and there is no requirement to document equipment that has been NRTL Listed or Accepted.
c. Non-NRTL equipment that is part of or an extension to a facility, such as building control systems, permanently-mounted multiple outlet assemblies, facility support machinery, etc., shall be surveyed and recorded in the database by the Facilities Division.
d. It is not necessary to survey standard office equipment, supplies, and appliances, such as computers, copiers, kitchen appliances, and desk lamps. This equipment is nearly always NRTL Listed or Accepted.

3. Multiple units. The following methods are used to evaluate multiple identical units of non-NRTL equipment.
    a. Each piece of equipment shall be surveyed, bar-coded, and entered into the database.
    b. One (or more, at the discretion of the inspector) representative model shall be inspected by an AHJ Field Representative.
    c. If the equipment passes inspection, all of the units are considered to have passed. The inspection record for all of the identical units shall reference the original inspection.
    d. If the equipment fails inspection, all of the units are considered to have failed. The inspection record for all of the identical units shall reference the original inspection.
4. Equipment from other DOE facilities. Equipment that has undergone inspection at another DOE Facility shall be considered to be acceptable if the inspection record is examined and found acceptable by an AHJ Field Representative. Such equipment shall be documented in the EEIP database, along with a copy of the inspection report.

5 Equipment Inspectors

1. EH&S will train and authorize EEIP Field Representatives to inspect equipment under the direction of the AHJ for Electrical Safety.
2. EH&S will train and authorize technically qualified designated Facilities employees to inspect equipment under the direction of the Facilities AHJ.
3. EH&S will train and authorize Engineering technologists to inspect equipment as it is being fabricated.

4. If other Divisions so request, EH&S will train and authorize other technically qualified designated employees to be EEIP Field Representatives. This will enable Divisions with special inspection requirements, such as user facilities, to control their own inspection processes.
5. Inspection costs by EH&S EEIP Field Representatives will not be charged back to the Divisions.

6 Examining and Approving Electrical Equipment

Equipment inspections shall not expose anyone to electrical hazards. All equipment shall be de-energized and LOTO'd as necessary (see PUB 3000, Ch. 18). If at any time the equipment inspector must come within the Limited Approach Boundary of exposed energized parts, the work must be authorized by an AHD.

All equipment that is subject to EEIP/AHJ inspection in accordance with Section 2 shall be inspected by one or more of the following methods.

6.1 120-volt commercially made cord-plug equipment.

Commercially made 120-volt, cord-plug connected equipment shall be inspected by an authorized EEIP Field Representative, using the following criteria. This process is expected to take no more than 1 hour per item, including documentation.

1. A visual inspection will be made to verify that the equipment is intact, undamaged, does not have any hazardous exposures, and is being used in accordance with its design intent.
2. The equipment will not be subject to any unusual environments, stresses or damage that may compromise safety.
3. An equipment test instrument will be used to verify that the equipment can withstand a prolonged high current in the grounding path, in accordance with established Standards for the equipment. Typically, a value of 0.1 ohms or less is required.
4. An equipment test instrument will be used to measure any line leakage to ground in accordance with established Standards. Line leakage must be less than 3.5mA for grounded equipment.
5. If the equipment is only powered by an NRTL Listed or Accepted "Class 2", "ITE", or "SELV" type power supply, the inspections and tests described in #3 and #4 above shall not be required. Such power supplies are power limited and do not present any hazard of shock or fire. The EEIP Field Representative shall verify the acceptability of the power supply and document the test in the database.

6.2 All other equipment

1. All elements in section 6.1 shall be satisfied.
2. In addition, a comprehensive checklist shall be completed, which will examine at minimum the following elements, as appropriate:

1. Enclosure
2. Mechanical Assembly
3. Wiring Compartments
4. Strain Relief
5. Switches and Controls
6. Extension cords & Power Strips
7. Bonding / grounding
8. Foreign Power Supplies & Equipment
9. Interconnect Wiring
10. Marking
11. Failure Modes
12. Modifications
13. Internal Wiring
14. Accessibility of Live Parts

Additional criteria will be applied at the discretion of the AHJ and Field Representative.

The effort for these inspections will vary considerably, but is expected to typically require 4 – 8 hours per item.

6.3 Active EEIP Involvement in the Design and Fabrication Process

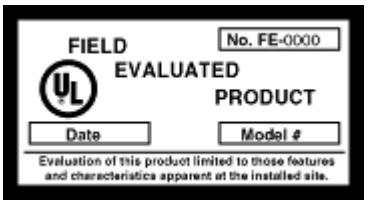
For custom designed and built equipment, it will typically be more efficient and effective to include EEIP involvement early in the process. In so doing, any safety issues can be resolved proactively, and final acceptance of the project will be assured.

At the onset of the project an EEIP representative will be assigned. The EEIP Representative will attend all engineering and project reviews as well as conduct routine safety inspections during the construction phase. At the conclusion of this process the equipment or project will be certified as being compliant and accepted as AHJ approved. Prior to placing the equipment into service, a minor inspection must be completed by the EEIP field representative or representative of the LBNL AHJ. Once the inspection has been passed, the equipment will have a label affixed to it certifying compliance.

6.4 Field Evaluation by NRTL or other Third Party

6.4.1 An NRTL or other third party Field evaluation shall be performed on non-NRTL equipment under any of the conditions described in 6.4.7.
6.4.2 This evaluation shall be done by an NRTL or an engineering firm that specializes in this type of assessment and is acceptable to the AHJ.
6.4.3This evaluation shall be funded by the organization that is responsible for the equipment.
6.4.5All documentation of such inspections shall be submitted to the EEIP Manager for review and approval.

6.4.6The Field Evaluation company shall appropriately label the equipment, for example:



6.4.7 Conditions requiring Field Evaluation

6.4.7.1 Purchase of equipment that exceeds $50,000 in value.

6.4.7.2 The EEIP Manager or other AHJ determines that the scope of examination of the equipment is beyond the capabilities of Field Inspectors

6.4.8 Equipment owners may also elect to retain 3rd party services in lieu of LBNL EEIP examination.

6.5 Facilities Infrastructure Equipment

Facilities electrical equipment installed that is associated with premises wiring or infrastructure is required to be NRTL-certified, if such is available. Non-NRTL equipment may be accepted based on the examination processes described above, or may be Accepted by the Facilities AHJ based on documented acceptance tests or other submittals provided by the equipment manufacturer or vendor.

The Facilities AHJ Field Representative(s) shall document Facilities equipment inspections in the EEIP database.

6.6 Reference Standards

Inspection criteria are drawn from recognized consensus Standards and engineering experience. An EEIP inspection is not equivalent to an NRTL Listing. The inspection elements described in 6.1 and 6.2 apply to most equipment. However, the EEIP inspector may elect to supplement (or substitute) these elements with other relevant criteria drawn from the following Standards or other Standards or tests as appropriate.

- UL 508; Industrial Control Equipment
- UL508A; Industrial Control Panels
- UL 61010-1; Electrical Equipment for Measurement, Control, and Laboratory Use
- NFPA 79, Electrical Standard for Industrial Machinery
- Livermore Specification for Equipment Fabrication (Appendix C)
- Documented acceptance tests provided by the equipment manufacturer

APPENDIX A Glossary

EEIP – Electrical Equipment Inspection Program

Equipment Supervisor - Also known as Responsible Person, or Equipment Owner. The Equipment Supervisor is the person who is most directly involved with using the equipment. The Equipment Supervisor should be directly knowledgeable about the function and intent of the equipment.

Field Evaluation – An equipment inspection performed by an NRTL on non-Listed equipment.

Legacy Equipment - Equipment that was obtained before February 1, 2009.

NRTL - Nationally Recognized Testing Laboratory. An organization which is recognized by OSHA and which tests for safety, and lists or labels or accepts, equipment based on established Standards: The NRTL is an independent third party and is not the manufacturer of the product or a government agency. A full list of NRTL labels is provided in Appendix B. The latest list of NRTL labels can be found at http://osha.gov/dts/otpca/nrtl/nrtlmrk.html.

Survey - The purpose of the NRTL survey is to create a **list** of electrical equipment that will later be inspected by a designated EEIP Equipment Inspector.

Surveyor - Personnel identified by their Division to conduct the NRTL Survey for their organization are referred to as Electrical Equipment Surveyors. Before conducting the survey, Electrical Equipment Surveyors must complete training course EHS0381.

APPENDIX B NRTL MARKS

This list is current as of January, 2009. For updates, see http://www.osha.gov/dts/otpca/nrtl/nrtlmrk.html


eti
NRTL


FM
APPROVED


C
FM
US
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ETL
LISTED


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Warnock Hersey


Warnock Hersey
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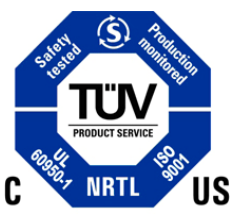
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UL 60950-1
ISO 9001
C NRTL US

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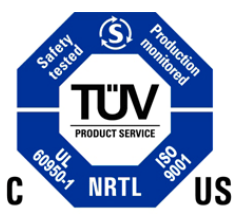
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of North America, Inc.
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Appendix C Inspection Program Labels

1) **AHJ Bar Code Label (Mandatory)** indicates that equipment needs to be inspected (or re-inspected). Specifically, the equipment is **not** NRTL certified and exceeds 50 volts potential and 5mA current capability, or it is NRTL equipment that has been modified.

2) **<u>Green</u> NRTL Label (Optional).** For equipment that **is** NRTL certified, hasn't been modified, and appears to be used as intended by the manufacturer, a green NRTL sticker may be initialed and affixed to the equipment in a visible location. This is a convenience to the surveyor and equipment supervisor, since the NRTL mark may not be readily visible. This label communicates that the NRTL mark appears somewhere on the equipment, so that others will not need to look for it. NRTL certified equipment is not tracked.

3) **<u>Red</u> Out Of Service Label.** Equipment that is not being used, is not intended to be used in the foreseeable future, and is not connected to an electrical source, is **not** required to be surveyed or inspected. This sticker informs the user that an inspection will be required before the equipment can be used.

Appendix D Livermore Specification For Electrical Equipment Fabrication

11.3 Specification for Electrical Equipment Fabrication

Revision History

Date	Author	Revision
November 2004	Teresa Hauck	Revision 0: Original release.

11.3.1 General

11.3.1.1 Scope

This specification sets forth the minimum requirements for the fabrication of single voltage source electronic equipment for Lawrence Livermore National Laboratory (LLNL). This specification applies to new equipment fabricated after the current revision date. Users must be aware that older equipment built to previous revisions of this specification may not conform to all current requirements.

11.3.1.2 Quality

The Laboratory's intent is to obtain the highest quality of materials and workmanship found in the best custom electronic equipment fabrication. Constructive suggestions for improving quality are welcome and will be given prompt consideration.

11.3.1.3 Materials

- Only new parts of current manufacture shall be used.
- Only components listed or recognized by a Nationally Recognized Testing Laboratory (NRTL) shall be used, e.g., UL, CSA-NRTL, ETL, etc. CE is not an NRTL. Equipment and components marked only with CE must be inspected and approved by an Authority Having Jurisdiction (AHJ) Field Representative. All components must be used in accordance with the manufacturer's intent and instructions and in accordance with NRTL specifications. All components must be rated for the voltage and current range for which they are used. Assemblies subject to high fault currents (>10,000 A) must either be rated to withstand the fault or appropriately protected with fast-acting fuses. Recognized components must be evaluated within the context of their component category. An updated list of NRTL marks can be found at: http://www.osha-slc.gov/dts/otpca/nrtl/nrtlmrk.html.
- The subcontractor shall advise LLNL of the discontinuance or renumbering of any parts by the part manufacturer.
- No substitutions may be made without the approval of LLNL.

11.3.1.4 Information Feedback

All changes agreed to between the manufacturer and LLNL shall be marked on one set of documentation, dated, and initialed. The preferred colors are red for deletions and green for corrections and/or additions.

The marked-up set of documents shall be returned to LLNL with the first "equipment" shipment (partial or complete).

11.3.1.5 Applicable Specifications

The latest revisions of the following documents form a part of this specification, to the extent stated herein:

Specification Number	Title
IPC-A-610	"Acceptability of Electronic Assemblies"
ANSI/J-STD-001	"Requirements for Soldered Electrical and Electronic Assemblies"
ASME Y14.5M 1994	"Dimensioning & Tolerancing"
EDSS Section 11.1	"Designing and Fabricating Safe Electrical Equipment"
IEEE 200-1975/ANSI Y32.16-1975	"Standard Reference Designations for Electrical and Electronics Parts and Equipment"
IEEE 315-1975/ANSI Y32.2-1975	"Graphic Symbols for Electrical and Electronics Diagrams"
IPC-CM-770	"Component Mounting Guidelines for Printed Boards"
IPC/WHMA-A-620	"Requirements and Acceptance for Cable and Wire Harness Assemblies"
LED 21872	"Cable Assemblies"
LED 43-01-15-A1	"Electronics Engineering Drafting and Design Manual"
MIL-A-8625	"Anodic Coatings for Aluminum and Aluminum Alloys" (Anodizing)
MIL-C-5541	"Chemical Conversion Coatings on Aluminum and Aluminum Alloys"
MIL-STD-104	"Limits for Electrical Insulation Color"
MIL-STD-681	"Identification, Coding, and Application of Hook-Up and Lead Wire"
MIL-DTL-16878	"Wire, Electrical, Insulated, General Specification for"
UL 486A-486B	"Wire Connectors"
UL 508A	"Industrial Control Panels"
UL 508	"Industrial Control Equipment"

11.3.1.6 Order of Precedence

In case of conflict, the fabrication "package" documents shall take precedence in the following descending order:

1. Statement of Work
2. Equipment performance specification
3. Schematic circuit diagram
4. Parts list

5. Other drawings in package
6. This and other specifications referenced herein
7. Product data sheets
8. Prototype or sample unit
9. Photographs

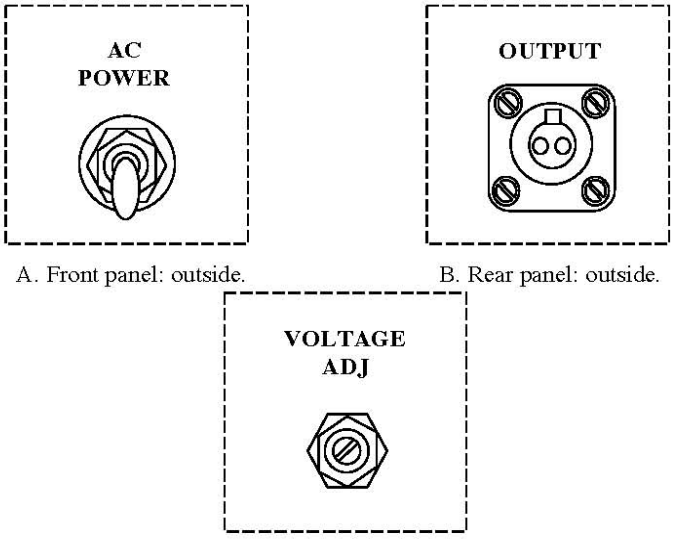
11.3.2 Marking

11.3.2.1 General

All markings shall be positioned for maximum readability.

Markings shall be legible and neat in appearance and shall display uniformity of style, size, spacing, and alignment of characters. Unless otherwise specified, marking height will be a minimum of 2.54 mm (0.100 inch) and a maximum of 4.0 mm (0.156 inch). Black ink shall be used on light backgrounds and white ink on dark backgrounds.

Function titles (shown in rectangular boxes on schematics) shall be marked above a component as shown in Figure 11.3-1.



A. Front panel: outside.

B. Rear panel: outside.

C. Chassis plates: on the surface where adjustment is made.

Figure 11.3-1. Marking locations for function titles.

The preferred location of a component reference designation marking (as indicated on the schematic) is below the mounted component for both chassis plates and the outside of rear panels. See Figure 11.3-2. When a component goes through the chassis plate, the component reference designation should be marked on both sides of the chassis plate. Typically, component reference designations do not appear on the outside of front panels.

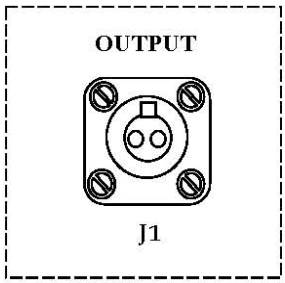


Figure 11.3-2. Marking location for component reference designation (rear panel, outside).

For the inside of both front and rear panels, the component reference designation markings above the chassis plate or front panel centerline shall be located above the component. Component reference designation markings below the chassis plate (or printed board assembly, shield, or other item that is mounted perpendicular to the front and rear panels) shall be located below the component and shall be read right side up when the chassis is upside down. When there is no chassis plate, the front panel centerline should be used as reference for marking orientation. See Figure 11.3-3.

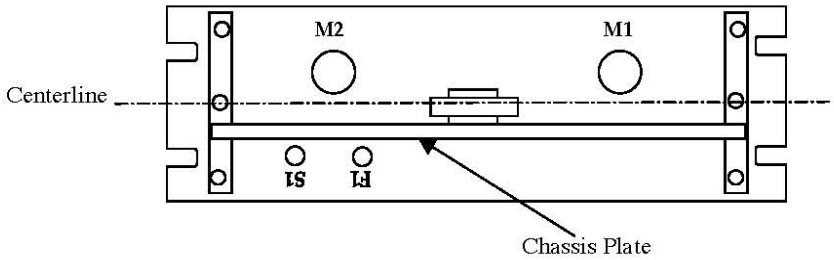


Figure 11.3-3. Marking locations for component reference designations (front and rear panels, inside).

When the component reference designation marking cannot be placed below the component, marking may be adjacent to the component. See Figure 11.3-4.

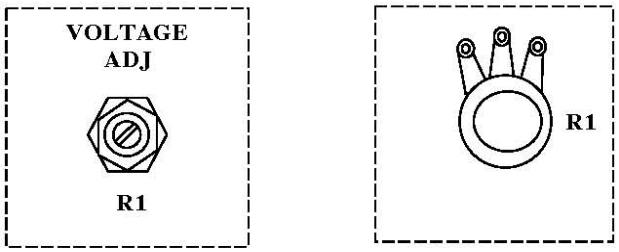
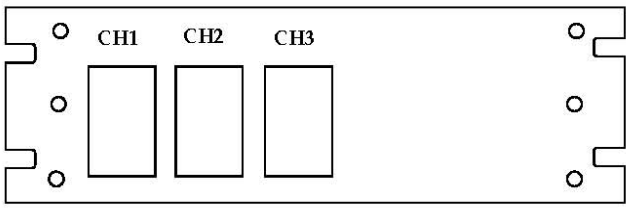
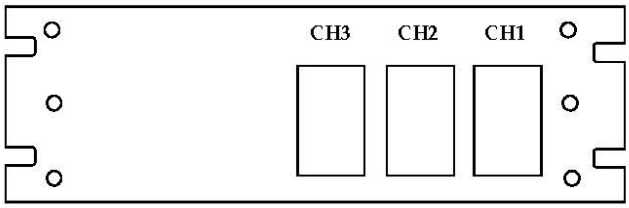


Figure 11.3-4. Component reference designation marking

Multichannel circuits within the same chassis shall be marked to read left to right from the operating face, as shown in Figure 11.3-5.



A. Front panel, outside.



B. Front panel, inside / Rear panel, outside

Figure 11.3-5. Multichannel circuit marking.

11.3.2.2 Front Panel

Markings on the outside of the front panel shall be silk-screened.

The title of the chassis unit shall be as shown in the title block of the schematic.

The drawing number of the chassis unit shall be as follows:

- For LEA numbers, the number will be composed of the letters "LEA" followed by the drawing number (8 digits) as shown on the assembly, if one exists. Otherwise, the schematic number will be used. **Note**: Revision level is omitted.
- If a tabulated assembly is used, the number will be composed of the letters "LEA" followed by the drawing number (8 digits) and the tab number (2 digits), for example: "LEA99-123456-01".

The title, drawing number, and serial number (S/N) shall be positioned as follows for a standard 19-in., rack-mounted chassis (see Figure 11.3-6):

1. Top of lettering shall be 1.59 mm (0.06 in.) from top edge of panel.
2. Drawing number is 50.8 mm (2.00 in.) from left edge of panel.
3. Serial number is 50.80 mm (2.00 in.) from right edge of panel.
4. Chassis title is centered on the panel.

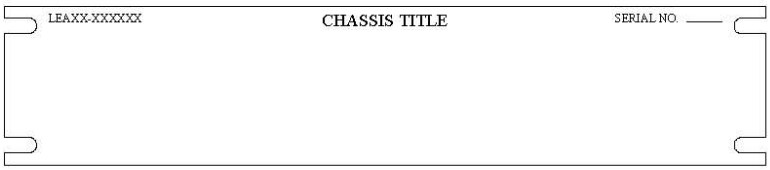


Figure 11.3-6. Positions of markings on the front panel.

11.3.2.3 Chassis Plates and Other Panels

Markings on other than the outside of the front panel may be applied with silk-screen, rubber stamp, or labels, and covered with protective coating if necessary.

Multichannel circuits within the same chassis shall be marked to read from right to left on the outside of the rear panel. See Figure 11.3-5B.

All schematic component reference designations should be marked below the referenced component. When space is restricted, marking may be adjacent to the component.

Component reference designations shall be in accordance with IEEE 200-1975. The marking shall be readable after assembly of components and wiring.

All markings on the top of chassis plates or top covers shall be readable from the front of the chassis.

All markings on the bottom of chassis plates or bottom covers shall be readable from the rear of the chassis.

11.3.2.4 Component Marking

Circuit breaker current ratings shall be marked on the back of the panel and be visible after chassis assembly (see Figure 11.3-7).

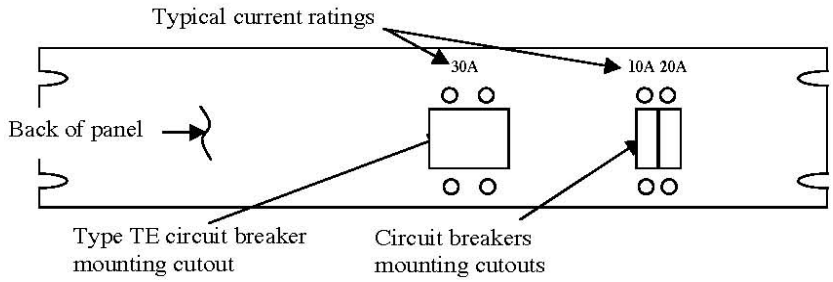


Figure 11.3-7. Location of markings for circuit breaker current ratings.

Plug-in components shall be marked with the component designation on the plug-in side and with the socket designation "X" preceding the component designation on the wiring side.

Terminal strips shall have the first and last contacts, and every fifth contact in between, marked on the panel. If the terminal strip is mounted through the chassis, marking shall appear on both sides.

Fanning strips, when used with a terminal strip, shall be marked in the same manner as a terminal strip.

Variable transformer swinger fuses shall be marked with the transformer component number and fuse rating.

All fuses shall have their amperage value and the words "SLO BLO" (if applicable) marked (see Figure 11.3-8).

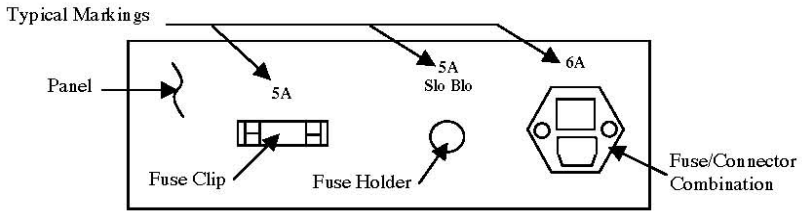


Figure 11.3-8. Marking for fuses.

Chassis with 250 V or more shall have a "CAUTION" or "DANGER" label attached or marked with the appropriate multicolored legend. See LED 43-01-15-A1 for more details.

All components mounted through a panel with leads or connections extending through the panel shall have their reference designations marked on both sides of the panel.

All components used for operating and maintaining equipment shall have their descriptive function (e.g., ON, OFF, Start, Stop, Voltage Adj., etc.) marked on the front (operating) side of the panel and the reference designation marked on the opposite side of the panel.

11.3.3 Assembly

11.3.3.1 General

Components marked with values and ratings shall be mounted so that they can be easily read. When it is not possible to mount a small component (such as a diode) to show both the part identification and polarity, the unit shall be mounted so the part identification marking is visible.

Equipment designed for use in areas other than a typical laboratory environment may call for additional fabrication requirements not included in this specification. Example environments include: high temperatures, cleanliness, vibration, and corrosive or explosive atmospheres. Design documentation shall be carefully reviewed to determine if there are any additional fabrication requirements.

Fastening hardware should be of the locking/captive type. Split or internal-tooth lock washers should be used when self-locking screws or nuts are not available.

Bolted or screwed electrical connections shall not depend on any insulating material to maintain contact pressure.

Ceramic and ceramic-coated parts shall be mounted with nylon or fiber washers in contact with the ceramic surfaces. Resilient washers shall be used whenever brittle materials are bolted in assembly.
When using threaded hardware, there shall be at least one thread visible beyond the front of the nut.

A flat washer shall be placed between the head of the screw and any non-metallic materials and over a slotted hole.

11.3.3.2 Component Mounting

Components with a mounting key slot, such as switches or potentiometers, shall be positioned with the slot on the bottom.

Chassis receptacles shall be mounted so that the key-way and/or first numbered or lettered terminal will be on the 12 o'clock position.

The ground pin of an ac receptacle should be oriented in the "up" position when mounted.

When heat sinks are specified for components, thermal heat sink compound or silpad should be used unless otherwise specified.

Control knobs and shaft couplings shall have metal inserts and be secured with two Allen-head set screws that are set at 90 degrees to each other.

When mounting an open-backed terminal strip on a metal surface, an insulating sheet 1 mm (0.04 in.) to 2 mm (0.08 in.) thick shall be used between the terminal strip and metal surface.

Semiconductors requiring lead trimming shall be sheared to the required length, not clipped with diagonal-jaw cutting pliers. Lead lengths shall be such that, when the device is fully inserted in the socket, there will be approximately 1 mm of space between the body of the device and its socket (see Figure 11.3-9).

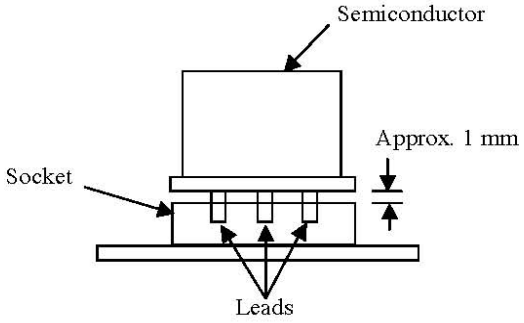


Figure 11.3-9. Appropriate amount of length for semiconductor leads.

Knobs shall be positioned on a shaft in accordance with manufacturer's specifications, or as shown in Figure 11.3-10.

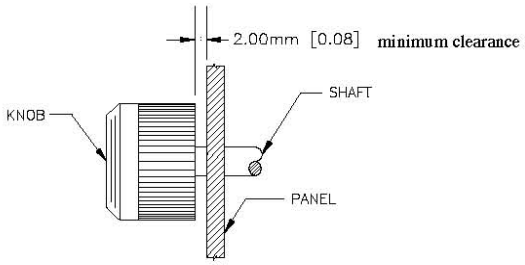


Figure 11.3-10. Knob positioning on shaft.

Fuse holders shall have a rubber washer between the fuse holder body and the panel.

Fan Assemblies shall have finger guards installed on the inside and outside of the chassis.

Multi-Deck Switches or potentiometers should have the "A" section of the switch or the lower "R" number closest to the mounting surface, as shown in Figure 11.3-11.

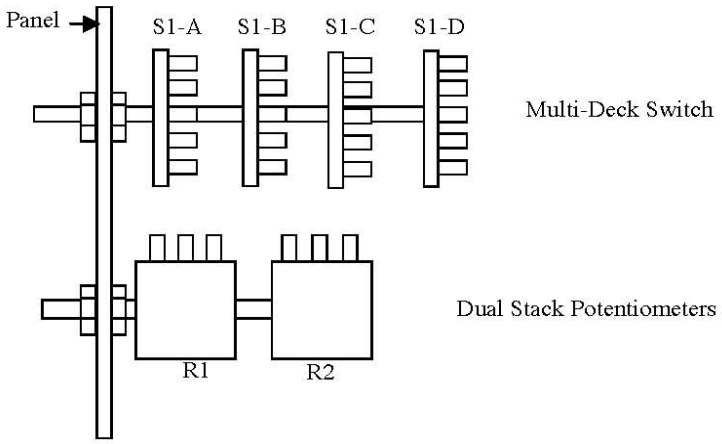


Figure 11.3-11. Proper marking order for Multi-Deck Switches or potentiometers.

Component leads shall extend beyond the component body at least 2 mm (0.08 in.) before any bend is made. There shall be at least 4 mm (0.156 in.) length between the component and the soldered connection.

11.3.4 Wiring

11.3.4.1 General

Tools used to shape leads shall not damage the leads. The use of round-nosed pliers or automatic lead-forming machines is recommended.

Interconnection leads should be provided with a service loop at the wiring termination unless identified by "Δ" on line of the schematic, in which case the wiring shall be as short as possible, but not taut.

Wires shall be arranged to prevent abrasion of the insulation. Long runs of wire shall be secured with ties or clamps.

All wiring connections should be accessible for maintenance.

Transparent tubing or shrink tubing should be used over wiring connections for inspection purposes.

Wiring of circuits greater than 1000 V shall have a minimum air clearance to ground and/or adjacent components of 25 mm (1.00 in.) per 10 kV. The voltage rating of separating insulation may be used to determine a reduced clearance. See table 11.3-1 for minimum clearance spacing for circuits having 51V to 600V.

Table 11.3-1. Summary of clearance/creepage distances.

From	To	Via	Rating, V Minimum Spacings, in. (mm)			
			51–150	151–300	301–600	Reference
Uninsulated live part	Uninsulated live part of opposite polarity or different circuit, or grounded part (not enclosure), or exposed metal part.	Through air	1/8 (3.2)	1/4 (6.4)	3/8 (9.6)	UL 508A, Table E
		Over surface	1/4 (6.4)	3/8 (9.6)	1/2 (12.7)	UL 508A, Table E
Uninsulated live part	Walls or fittings of metal enclosure	Shortest distance	1/2 (12.7)	1/2 (12.7)	1 (25.4)	UL 508A, Table E; NEC 373; NFPA79; 12.5.2, NEC Art. 373
Uninsulated live part	Any uninsulated part of the enclosure door	Shortest distance	1 (25.4)	1 (25.4)	1 (25.4)	NEC 373
Edge of any mounted device	Between the device and the enclosure walls	Shortest distance	1/16 (1.6)	1/16 (1.6)	1/16 (1.6)	NEC 373

11.3.4.2 Grounding and Bonding

"Equipment grounding" generally refers to the connection of the equipment to the electrical system equipment-grounding conductor. "Bonding" generally refers to the practice of establishing electrical continuity between all exposed metal surfaces such that there is no potential between any two surfaces.

Bonding wires must be securely terminated. All grounding and bonding wires shall be attached by dedicated means. The hardware used for grounding or bonding shall not have any other purpose. A grounding conductor that enters the equipment shall be terminated in a pressure wire connector that is clearly marked as a grounding connection. Only one conductor may be terminated in the connector. Solder connections or sheet metal screws shall not be used for grounding or bonding purposes.

All metal not carrying a current must be properly bonded. All exposed metal parts must be positively bonded to one another. Surface contact of anodized aluminum is not acceptable for grounding and bonding. The anodizing must be stripped away to allow

adequate electrical contact, or a bonding wire must be installed between anodized surfaces. Metal surfaces that are securely bolted together are considered bonded if:

- Sufficient area between the surfaces is clean of paint and other coatings to ensure good metal-to-metal contact.
- Bolt heads and nuts/washers are fully in contact with clean, uncoated metal surfaces. Any enclosure intended for access by the user shall have an internal copper bonding wire installed between the access panel and a bonded surface. A hinge does not constitute bonding unless it is listed by an NRTL or recognized for this purpose. Connections dependant on friction are not acceptable for grounding or bonding.

Where there are removable or hinged portions of a box or chassis with components, a separate bonding wire is required between the removable or hinged portion and the box or chassis to ensure a proper ground.There shall be a ground screw assembly located and labeled " ⏚ " or "EG" on the chassis plate. See Figure 11.3-12. The sole purpose of this assembly is to establish an earth ground. The area on the chassis plate where the ground screw assembly is installed shall be clean of paint, anodizing, and other coatings to ensure metal-to-metal contact. Apply a light coat of an oxide inhibitor, such as Penetrox, in the corrosion area before installing ground screw hardware.

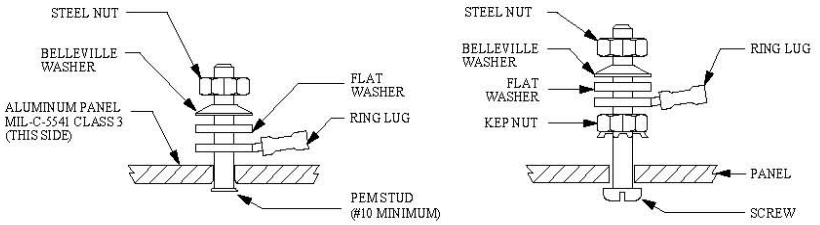


Figure 11.3-12. Ground Screw Assembly Options (Minimum hardware size is #10)

For tightening torque required for connecting hardware, i.e., ground screw assembly, see Table 11.3-2.

Table 11.3-2. Tightening torque for connecting hardware.

Screw or bolt size		Tightening torque	
Metric	**(SAE)**	**N·m**	**(lbf·ft)**
—	(No. 8 or smaller)	2	(1.5)
—	(No. 10)	3	(2.0)
M6	(1/4 in.)	8	(6)
—	(5/16 in.)	15	(11)
M10	(3/8 in.)	26	(19)
—	(7/16 in.)	41	(30)
M12	(1/2 in.)	54	(40)
—	(9/16, 5/8 in. or larger)	75	(55)

11.3.4.3 Wire Termination

Terminal connectors (lugs) shall be closed-ring and have the proper stud size and wire gauge. The barrel of the lug shall be filled with solder or crimped.

Crimp terminals shall be used with stranded wire only, unless the product is specifically designated for solid wire.

Only one wire is to be used per terminal connector unless the connector is designed for more than one wire.

No more than three terminal lugs shall be attached to a bolt or screw.

Solid wire must be wrapped three-quarters to seven-eighths of a turn around wire binding screws in the direction of the tightening screw. Stranded wire may be wrapped around wire binding screws only if the wire is tinned or soldered, or terminals have cupped washers, upturned edges, or other means of capturing all the strands.

Two wires are allowed in pressure connectors if the connectors are designed for two.

Wires shall not be spliced. The insulation on a wire shall be continuous between terminations.

Unused component wire leads, such as a transformer center tap, shall be terminated at tie points.

A tie point shall be used for the junction of two or more wires and/or the termination of single component leads.

Unused terminals on any component shall not be used as tie points.

When solid wire is specified, the wire may be terminated with a lug or soldered to a terminal.

A sound mechanical connection of all wires to a terminal point should be made before applying solder.

Thermocouple wire that terminates at a screw may be terminated by looping wire around the screw three-quarters to seven-eighths of a turn in a direction that will tighten the loop when the screw is tightened.

11.3.4.4 Wire Routing

Grommets shall be used to protect wires passing through metal surfaces.

Wires within a wire harness should be parallel with a minimum of crossover. The harness shall be routed to eliminate interference with components, contact with heat-dissipating items, or abrasion on sharp or rough edges. Special consideration should be given to routing wire harnesses within a chassis that contains a combination of digital signal, relay control power, ac voltage, and high voltage.

Tie-wraps or nylon lacing shall be used for bundling wires. Ties at breakouts should be made as close as possible to each side of the breakout and as close to each side of the bend without placing the tie in the bend itself. Sufficient tie-down clamps must be used to secure all wiring harnesses to chassis.

Terminal blocks for power circuits shall be grouped separately from control circuits. Internal ac power conductors are to be segregated from other conductors.

11.3.4.5 Wire Types and Sizes

All internal wiring must be either Listed or Machine Tool Wiring (MTW). All internal wiring must be copper, except thermocouple or special-purpose wire. Insulation must be rated for the highest voltage on any adjacent (bundled) wire.

Hook-up wire shall be per MIL-DTL-16878G, Types M16878/2, /18, or M16878/3, /19 for vinyl and NEMA HP 3 for Teflon. Wire-wrap wire shall be Kynar (polyvinylidene fluoride) insulated. All chassis hook-up wire shall be sized as indicated in Table 11.3-3. The preferred chassis wiring size and type is 18 AWG Teflon or larger.

Table 11.3-3. Sizes of chassis hook-up wire.

Maximum Current (A)	AWG Vinyl	AWG Teflon
3	22	24
4	20	22
5	18	20
7	16	18
10	14	16
15	12	–
20	10	–
30	8	–

11.3.4.6 Color Code

Color values shall be within the limits defined in MIL-STD-104.

Chassis hook-up wire shall be coded as shown in Table 11.3-4.

Table 11.3-4. Chassis hook-up wire color codes by function.

Color	Function
Green	Grounds, grounded elements, ac ground
Brown	Heaters or filaments
Red	Primary power supply, B+
Orange	Screen grids clock
Yellow	Cathodes and transistor emitters, high logic
Black	Control grids and transistor bases, ac "hot"
Blue	Anodes (plates) and transistor collectors, control
Violet	Primary power supply—minus voltage
White	ac neutral

Chassis wiring for dc power shall be coded as shown in Table 11.3-5.

Table 11.3-5. DC power coding for chassis.

Wire Color	Voltage (V)
Red	+151 to +500
White/Red	+61 to +150
White/Brown/Red	+26 to +60
White/Red/Orange	+7 to +25
White/Red/yellow	+2 to +6
Violet	–26 to –60
White/Violet	–11 to –25
White/Violet/Yellow	–2 to –10
Green	Ground

Color-coding, as listed in Table 11.3-6, should be used for ac power wiring.

Table 11.3-6. Color coding for ac power wiring (100 V and greater) for single and three phase systems.

Service	Phase A	Phase B	Phase C	Neutral	Ground
115V 60 Hz 1ϕ	Black	—	—	White	Green
208V 60 Hz 3ϕ "Y"	Black	Red	Orange or Blue	White	Green
230V 60 Hz 3ϕ delta	Black	Red	Orange or Blue	—	Green
115V 400 Hz 3ϕ delta	Black	Red	Orange or Blue	—	Green
208V 400 Hz 3ϕ "Y"	Black	Red	Orange or Blue	White	Green
480V 3ϕ	Brown	Yellow	Violet	White	Green

Color-coding, as listed in Table 11.3-7, should be used to indicate terminal and power cord polarity.

Table 11.3-7. Color-coding used to indicate polarity.

NEC	Power Line		Power Cord Wire	
Convention	Terminal	AC Connector Terminal Pin	US	European
Energized	"Hot"	Brass	Black	Brown
Grounded	"Neutral"	Silver/Nickel	White	Blue
Grounding	"Ground"	Green (round or U-shaped pin	Green	Green with stripe

11.3.4.7 Miscellaneous

AC wiring shall be twisted unless otherwise specified. Preferably, ac wiring will be routed on the underside of the chassis plate and/or routed separately from other wires.

Potentiometers and variable resistors shall be wired so that "CW" or an arrow designates clockwise rotation as viewed from the shaft end.

Any voltage-dropping resistance used with an indicating light shall be connected between the light and the "hot" or primary voltage source (see Figure 11.3-13).

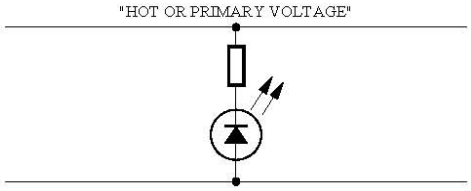
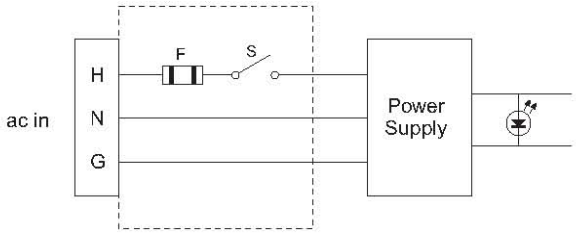


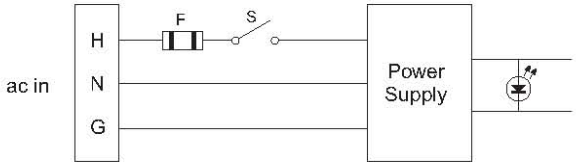
Figure 11.3-13. Typical resistor connection to indicating light.

For branch circuit input power circuit configurations, it is recommended that the line fuse be installed adjacent, and as close as practical, to the input power entry point using minimal internal chassis wiring (see Figure 11.3-14).

The line fuse—power switch—load combination would provide superior electrical circuit and fire hazard protection for the line-to-ground-fault condition. In this configuration, there will be minimal internal chassis wiring between the line-power entry point and the line-side fuse terminal. This minimizes reliance on the impedance and rating of the internal chassis line-side wiring and components for line-to-ground-fault protection. With this configuration, the internal chassis fuse rating will be the primary protection device for line-to-ground-fault conditions.



A. Using ac power module



B. Hardwired circuit

Figure 11.3-14. Preferred branch circuit input power circuit configuration.

The alternate branch circuit input power configuration shown in Figure 11.3-15, power switch—line fuse—load, would appear to provide additional electrical shock protection to the individual checking and/or replacing the line fuse while the equipment is connected to a live branch circuit. However, this configuration exposes additional internal chassis wiring to a possible branch-circuit-to-ground fault. The additional internal wiring—between the branch circuit line power entry point through the switch to the line side of the fuse terminal—will rely on the branch circuit over-current device for ground fault protection. The impedance of the internal chassis wiring and current rating of the power switch would be critical for providing sufficient fault current to trip the branch circuit over-current device without causing damage to these components subjected to the branch circuit fault current potential.

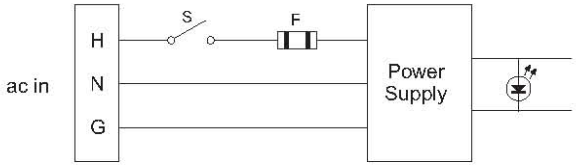


Figure 11.3-15. Alternate branch circuit input power circuit configuration.

When using the alternate branch circuit input power configuration, the power cord and internal chassis wiring shall be no less than 16 AWG and the internal chassis wiring shall be no more than 36 in. in length. The chassis power switch shall be rated to perform under the anticipated branch circuit fault current conditions.

Incoming or "line-side" ac wiring shall be connected to components as follows:

Components	Connection
Switch, single-throw, terminals on each end	Top terminal
Switch, double-throw (used as single-throw)	Swinger

All exposed ac voltage wiring shall be covered for safety in an appropriate manner, such as with a nonconductive material like Lucite or shrink tubing that is NRTL listed for this purpose.

It shall be verified that the chassis is free of sharp burrs, metal shavings, wire clippings, solder splatter, and other foreign material that could cause electrical shorts.

11.3.5 Quality Assurance

The manufacturer shall perform all specified tests and inspection requirements, and shall verify that the materials, dimensions, markings, and workmanship meet requirements.

Manufacturers' test equipment, inspection methods, and test data shall be acceptable to LLNL. A certificate of conformance shall accompany each shipment of product when specified.

Appendix E Contact Information

EEIP / AHJ Contacts:

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JSRidgeway@lbl.gov

AHJ Engineering
Kem Robinson, Engineering Division Director
510-486-4200
KERobinson@lbl.gov

Field Evaluation Programs:

UL Field Evaluation Program
877-854-3577
http://www.ul.com/field/

SGS
1.800.777.TEST
http://www.us.sgs.com/fieldlabel.htm

MET
510-489-6300
http://www.metlabs.com/pages/field.html

ETI
http://www.eticonformity.com/FieldEval.htm

FM
781 255 4850
http://www.fmglobal.com/page.aspx?id=50010105